Chapter 3
HEC-IFH Program Concepts and Applications

3-1. General

a. HEC-IFH is an interactive PC program using the MS-DOS system. The program is used for interior flood analyses based on continuous records or hypothetical and/or historic events. HEC-IFH facilitates technical computations, and helps manage the often complex and tedious task of data processing required for conducting interior studies.

b. HEC-IFH enables full-screen, interactive data entry, with input data verification and plotting prior to running the program. Analysis methods are selected using program menus. The analysis may be performed in steps, with the opportunity to review and assess results after each step. Reports and plots may be generated from input and output data. Additional output may be retrieved later without repeating the program execution. Detailed information about the program is available in the HEC-IFH Package user's manual (USACE 1992).

3-2. Computer System Requirements and Program Structure

a. Computer hardware requirements. HEC-IFH requires an IBM PC-compatible computer based on an 80386 or greater microprocessor. HEC-IFH also requires a math coprocessor for the 80386 or 80386SX computers. The operating system must be MS-DOS or IBM PC-DOS (version 3.0 or higher). The computer must have 4 MB of RAM memory as a minimum, with at least 3 MB configured as extended memory. A hard disk with at least 3.2 MB of storage capacity is required to install the HEC-IFH program and an additional 2.5 MB to copy and use CSA and HEA test data files. Significant storage is required if the CSA method is used, with a plan using 40 years of continuous record data at 1-hr increments requiring 8-10 MB of free space. Appendix B of the HEC-IFH user's manual suggests a minimum of 2 MB of free space for the HEA method.

b. Use of HEC-DSS. A key feature of the HEC-IFH program is the use of the HEC Data Storage System (HEC-DSS, USACE 1992) to store analysis input and output. Data can be imported from HEC-DSS interactively from within the HEC-IFH program. Also, data from other computer applications such as HEC-1 (USACE 1990b) can be imported directly as input to the HEC-IFH program. All HEC-IFH output is written to HEC-DSS and may be used by other programs that access HEC-DSS.

3-3. Program Menu Structure

HEC-IFH uses a menu screen format from a hierarchical (tree-like) structure to select different program options. Figure 3-1 illustrates the program menu structure. An introductory screen is displayed showing the name and version of the program at the beginning of every interactive session. Proceeding to the next screen, the user is asked to create a study ID subdirectory or recall an existing study subdirectory. All data for plans associated with a given study are stored in this subdirectory. An example of an opening menu is shown in Figure 3-2.

3-4. Program Configuration and Data Management Utilities

The main menu screen follows the study ID screen and allows the user to select different options for program use. The Main Menu selections (Figure 3-3) are Program Configuration Options, Data Management Utilities, Continuous Simulation Analysis, and Hypothetical Event Analysis.

- **Program Configuration.** HEC-IFH allows several configuration options to be set. These options control the appearance of program screens, plots, and printed reports. The units of measurement can also be specified.

- **Data Management Utilities.** HEC-IFH uses a Data Management Menu screen to list, archive, retrieve, and delete selected input and output data for a study or plan. Appendix D of the HEC-IFH user's manual describes the use of the menu screen in detail.

3-5. Program Application Structure

a. When either CSA or HEA is selected from the HEC-IFH Main Menu (Figure 3-3), the following choices are presented (see Figure 3-4):

- **Define Interior Analysis Data:** Allows input data to be entered or edited.

- **Perform Interior Analysis:** Allows definition of a plan for analysis.

- **Hydrologic Analysis Summaries:** Allows display of the results of a single interior analysis plan.

- **Comparison of Plans:** Allows display of a comparison of the hydrologic results of up to seven different interior analysis plans.

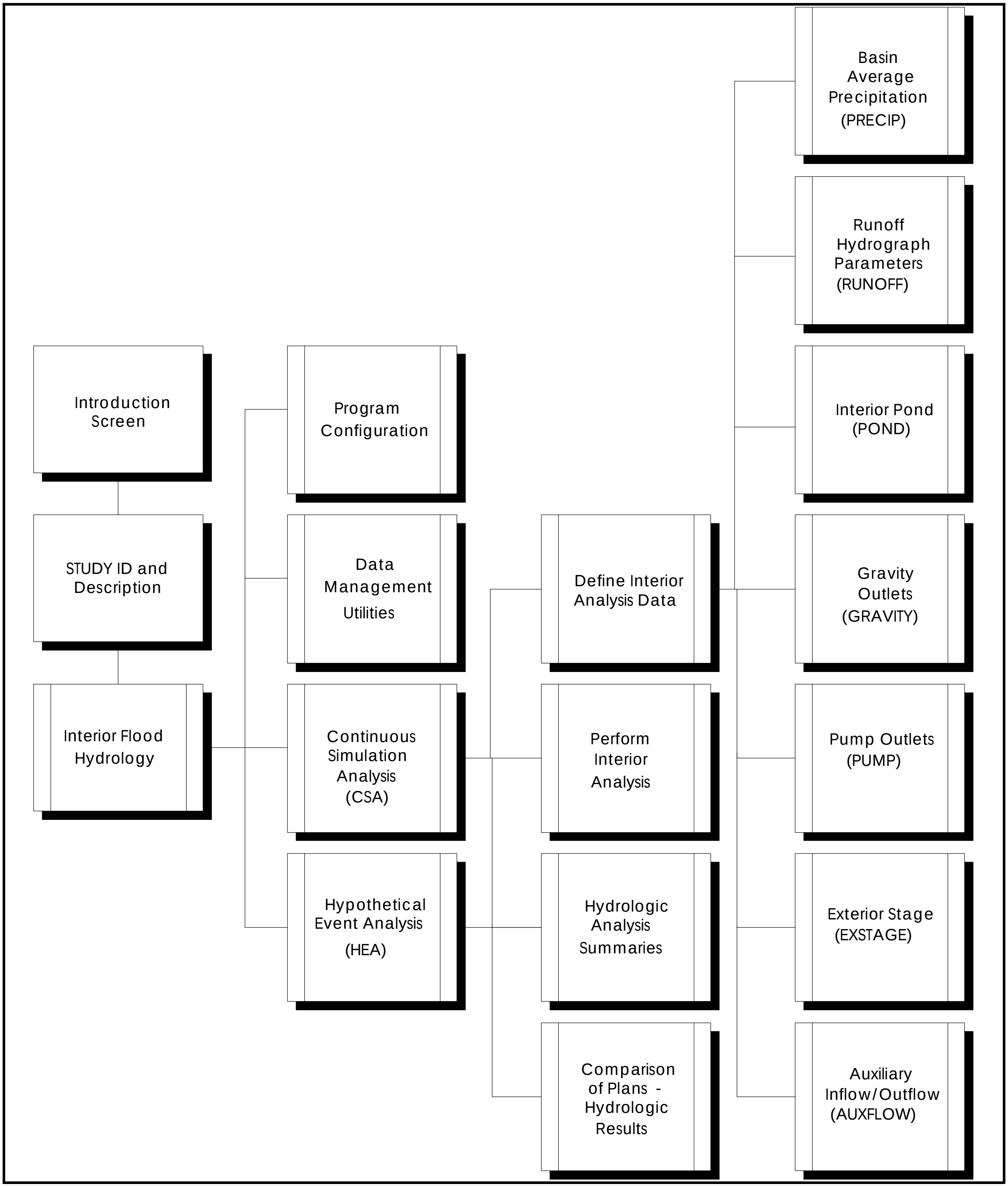

Figure 3-1. HEC-IFH program menu hierarchy

```
IFH 01.04.00
                    H.E.C. INTERIOR FLOOD
                 HYDROLOGY ANALYSIS PROGRAM
                      Version 01.04.00

         Study ID:          RBEND1
         Short Description: Plan 1 results - CSA example, App. C.

         Full Description:  The complete Plan 1 results are provided
                            for the CSA Example described in
                            Appendix C of the HEC-IFH User's Manual.

                            You may wish to view the study results
                            by pressing F10 to continue or work
                            through the example by following the
                            instructions in Appendix C.

         System of Measurement:       [English/Imperial] Metric/S.I

1Help   2PrtScr 3Index  4       5       6DOS    7       8       9       10Exit
          Press <Esc> to Quit program; or <F10> to Proceed to the Menu
```

Figure 3-2. Study ID and descriptions

```
IFH 01.04.00
Study ID  RBEND1       H.E.C. INTERIOR FLOOD HYDROLOGY




                    Select Option:

                      A. Program Configuration Options
                      B. Data Management Utilities
                      C. Continuous Simulation Analysis (CSA)
                      D. Hypothetical Event Analysis (HEA)




1Help   2PrtScr 3       4       5       6DOS    7       8       9       10Exit
              Press Letter; or use Arrow Keys and <Enter> to Select
```

Figure 3-3. HEC-IFH main menu

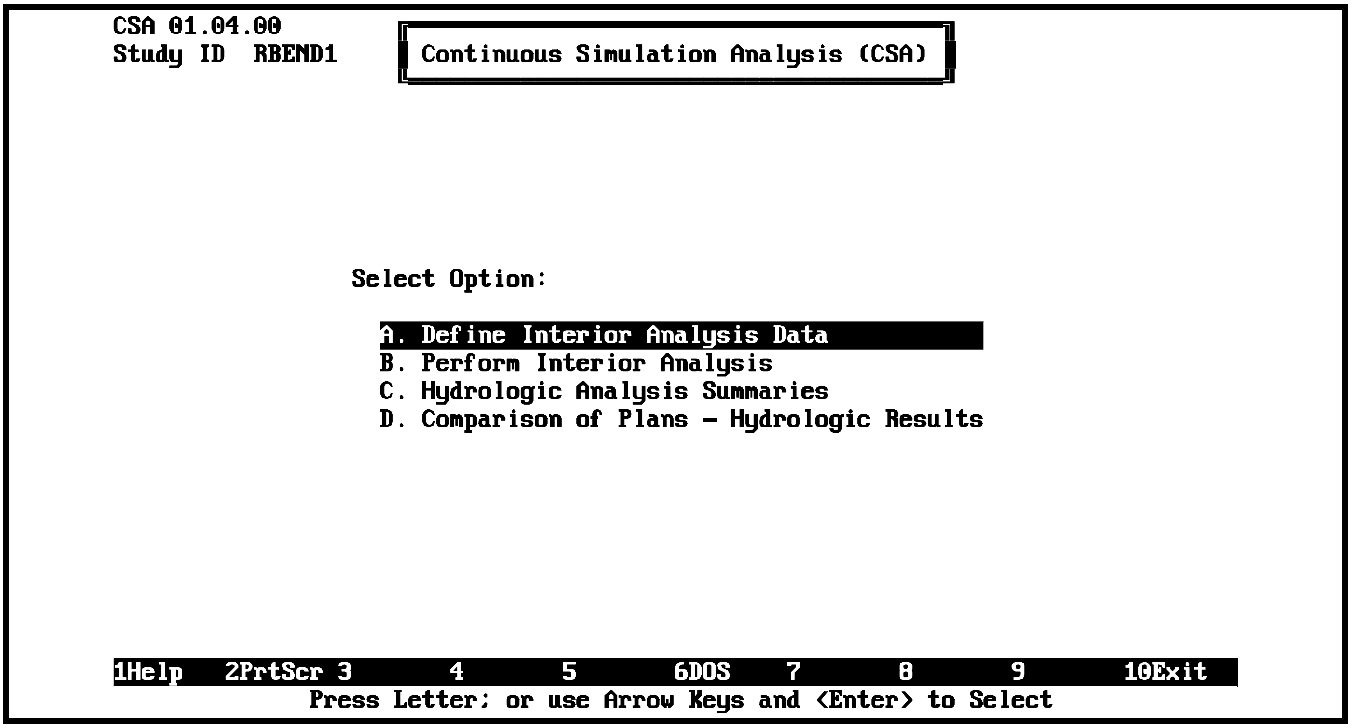

Figure 3-4. HEC-IFH continuous simulation analysis menu

b. The initial step is normally to define the interior analysis data for the study. This chapter emphasizes data entry procedures for accomplishing this task.

3-6. Define Interior Analysis Data

a. Data requirements. Data that define the interior and exterior are required to perform an interior area analysis. The information presented here can be used for any analytical method, but is specifically targeted for HEC-IFH data entry. Analyses are assumed to use both continuous record and hypothetical event approaches. The tasks are:

(1) Define interior areas to be studied. Consider the line-of-protection alignment, minimum facility requirements, runoff topology, topography of local ponding areas, present storm sewer systems, and potential for additional storm water collector/conveyance systems.

(2) Delineate interior subbasins considering locations needed for stage-frequency relationships and storm sewer configuration.

(3) Select computation time interval (Δt) for this and subsequent analyses. Refer to Section 3-7 for more details in determining appropriate computation intervals.

b. HEC-IFH modular concepts. Data entry is performed after the study ID and type of analysis are specified. The HEC-IFH program uses a modular data entry format to store the input data needed to execute a plan. The modules contain all the data needed for a specific category of information. Seven modules are used to represent groups of related data (Figure 3-5). The program provides separate data entry screens and computational procedures to develop the data for each module. Several sets of data may be entered and stored with module identifiers (module ID's) identifying each set. The seven modules are:

- **PRECIP Module:** Basin Average Precipitation.
- **RUNOFF Module:** Runoff Hydrograph Parameters.
- **POND Module:** Interior Pond Data.
- **GRAVITY Module:** Gravity Outlet Data.
- **PUMP Module:** Pump Outlet Data.
- **EXSTAGE Module:** Exterior Stage Data.
- **AUXFLOW Module:** Auxiliary Inflows and Outflows.

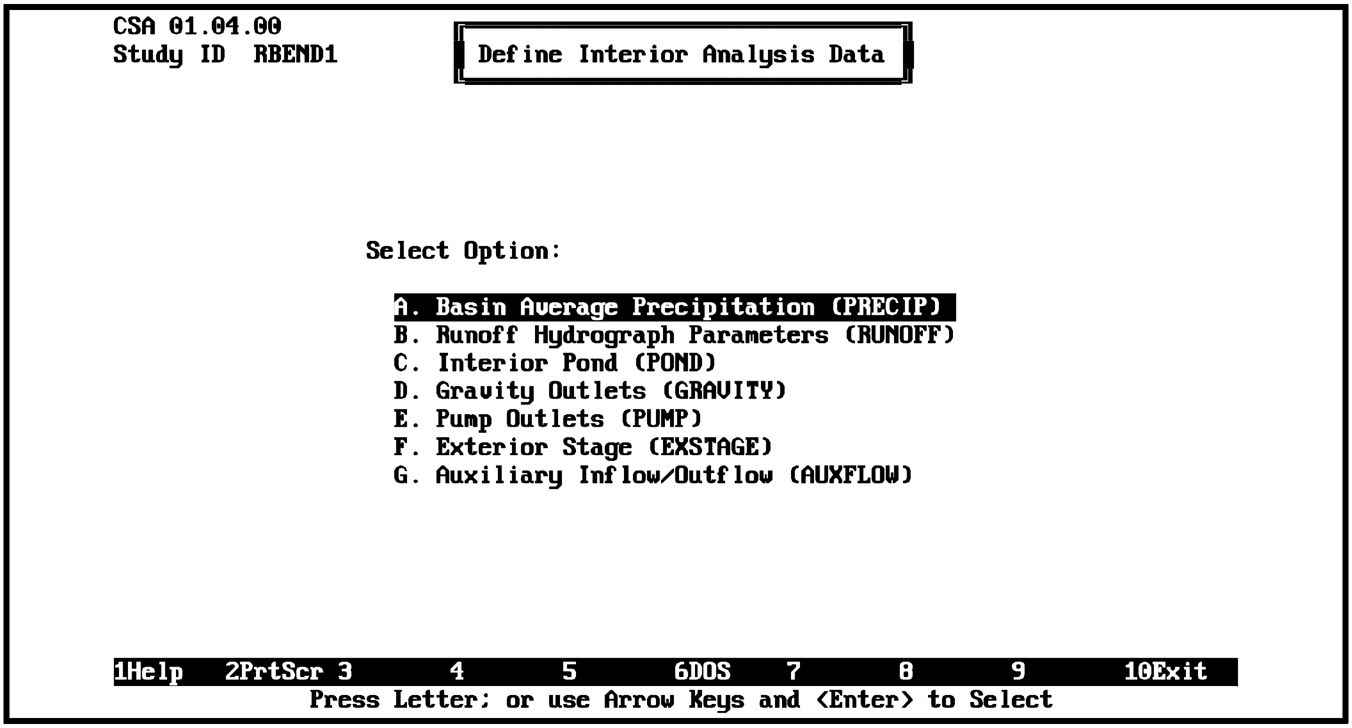

Figure 3-5. HEC-IFH data entry menu

(1) PRECIP module.

(a) This module contains continuous rainfall (normally historic records) and/or historical storm records and hypothetical frequency event data. Runoff computations require subbasin rainfall records.

(b) Rainfall data for recording and nonrecording rain gauges generally can be obtained from the National Weather Service (NWS) publications or CD's. Figure 3-6 shows what data can be obtained from the National Climatic Data Center. Estimates of rainfall data may also be acquired from newspaper articles that describe flooding after a large storm event and from rain gauges placed by local citizens, drainage districts, public works departments, and college or university science departments.

(c) Rainfall data can be entered into HEC-IFH manually, or imported from an existing HEC-DSS database. HEC-IFH checks imported values for missing data and either replaces them with zeros, or terminates the procedure. It is recommended to correct missing values using external utilities before importing them to HEC-IFH. One-year, one-month, or one-day hyetograph plots can be generated from the rainfall data. Figures 3-7 and 3-8 show precipitation data entry screens for CSA and HEA, respectively.

(d) HEC's PRECIP program is a useful tool for developing continuous basin average precipitation records from area recording and non-recording rain gauge data. See the PRECIP user manual (USACE 1989) for more information.

(e) Hypothetical frequency storm depth-frequency-duration relationships are normally developed from standard rainfall depth-frequency-duration information published by the National Weather Service. These data are entered into HEC-IFH as illustrated in Figure 3-8. HEC-IFH uses this information to compute rainfall distributions for up to seven storms ranging from 50 percent to 0.2 percent exceedance frequency. Figure 3-9 illustrates a rainfall hyetograph for a hypothetical storm.

(f) HEC-IFH allows the user to compute a standard project storm (SPS) using the same computation method utilized in the HEC-1 computer program. The SPS is normally used to generate a large event to evaluate how the system would perform if the event occurs. Figure 3-10 illustrates a typical SPS precipitation distribution.

(g) After the rainfall records are adjusted and verified, weightings are assigned to each gauge so that a composite rainfall record is developed for each subbasin. The weightings are based on conventional methods as described in Section 3.2.2 of the HEC-IFH user's manual.

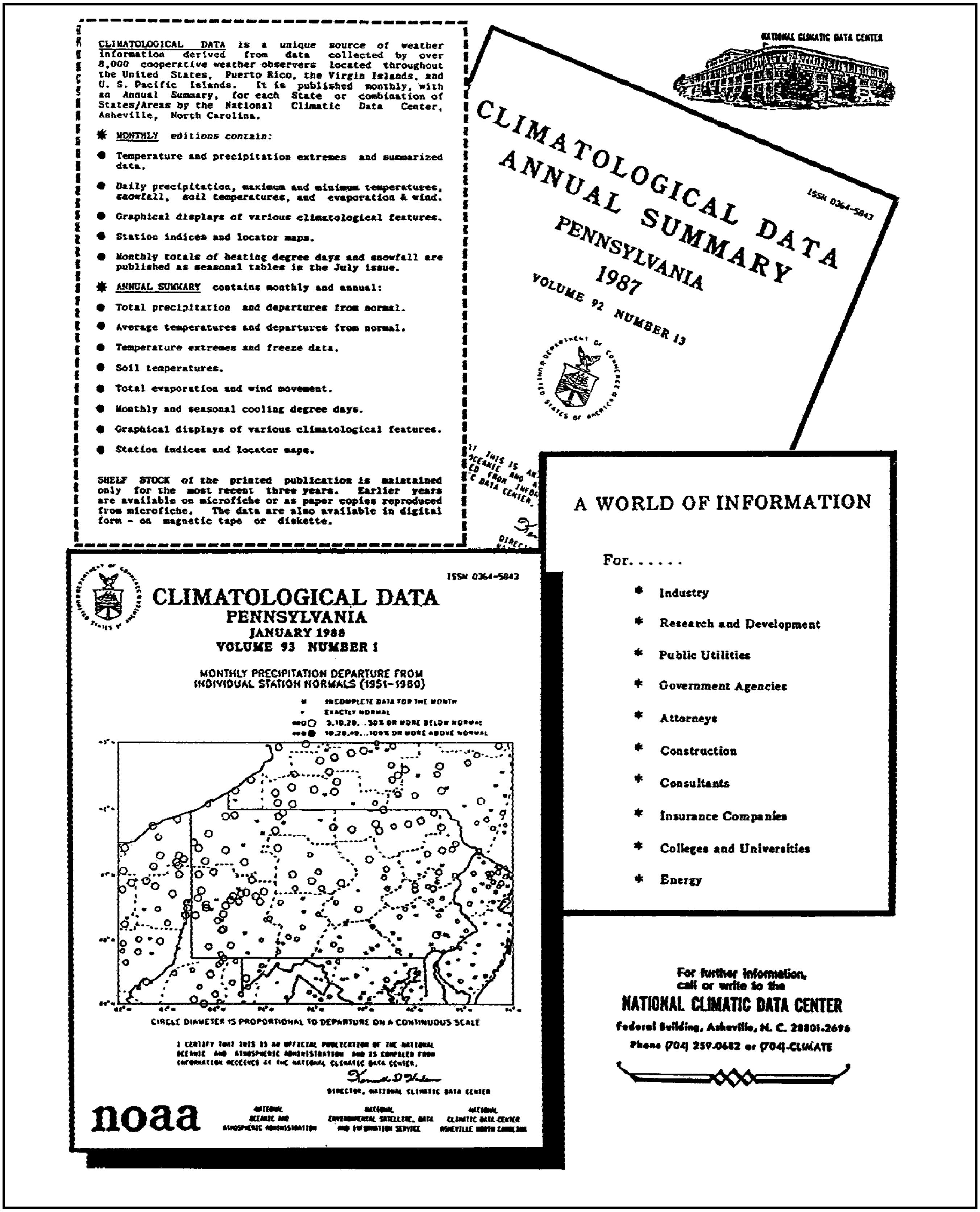

Figure 3-6. Source of climatological data

CSA 01.04.00
Study ID RBEND1

Basin Average Precipitation (PRECIP)

Enter/Import Precipitation Station Data

Precipitation Station ID GAGE1
Description:
Gage 1 recorded precip. WY1950-WY1960

Starting Period 01OCT1950/0100
(e.g. 01JAN1989/1300)

Ending Period 30SEP1960/2400

Time Interval 1HOUR
(e.g. 1HOUR, 1DAY, ...)

Date/Time DaMonYear/HrMn	Precipitation (in)
10OCT1954/0100	0.19
10OCT1954/0200	0.13
10OCT1954/0300	0.13
10OCT1954/0400	0.21
10OCT1954/0500	0.28
10OCT1954/0600	0.21
10OCT1954/0700	0.10
10OCT1954/0800	0.01
10OCT1954/0900	0.03
10OCT1954/1000	0.17
10OCT1954/1100	0.14
10OCT1954/1200	0.03
10OCT1954/1300	0.02
10OCT1954/1400	0.05

1Help 2PrtScr 3Index 4 5 6DOS 7 8 9 10Exit
Press <F10> to Save Data and Return

Figure 3-7. CSA precipitation data entry

HEA 01.04.00
Study ID RBEND1
Module ID STORM1

Basin Average Precipitation (PRECIP)

Enter Partial-Duration Rainfall Depth-Duration-Frequency Data

Duration	Rainfall Depth (in) for each Hypothetical Event						
	50%	20%	10%	4%	2%	1%	0.2%
5 minutes	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15 minutes	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1 hour	1.50	1.65	1.95	2.30	2.50	2.75	3.20
2 hours	1.80	2.00	2.30	2.70	2.90	3.25	3.60
3 hours	2.20	2.40	2.60	2.90	3.25	3.60	4.00
6 hours	2.40	2.60	3.00	3.50	3.80	4.25	4.70
12 hours	2.60	3.00	3.50	4.00	4.50	5.00	5.60
24 hours	2.80	3.50	4.00	4.60	5.20	5.70	6.20
2 days	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4 days	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7 days	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10 days	0.00	0.00	0.00	0.00	0.00	0.00	0.00

1Help 2PrtScr 3 4 5 6DOS 7 8 9 10Exit
Press <F10> to Save Data and Continue

Figure 3-8. HEA precipitation data entry

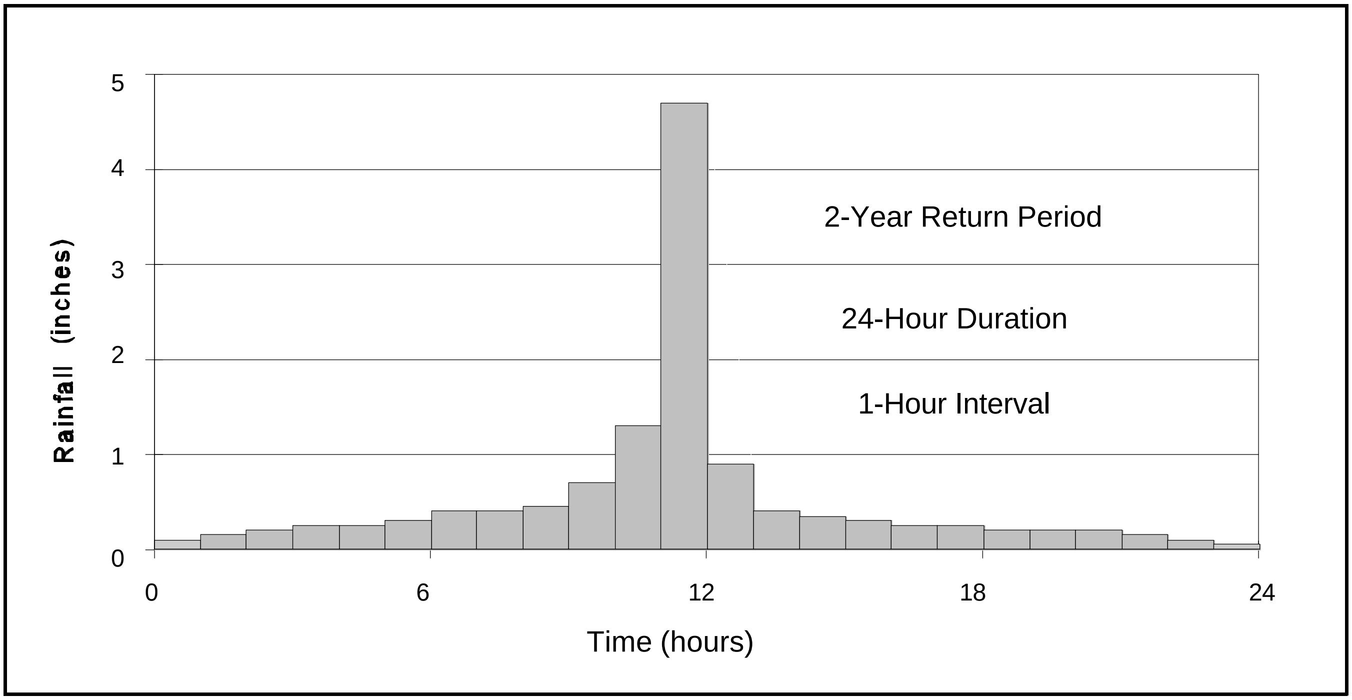

Figure 3-9. Hypothetical frequency storm hyetograph

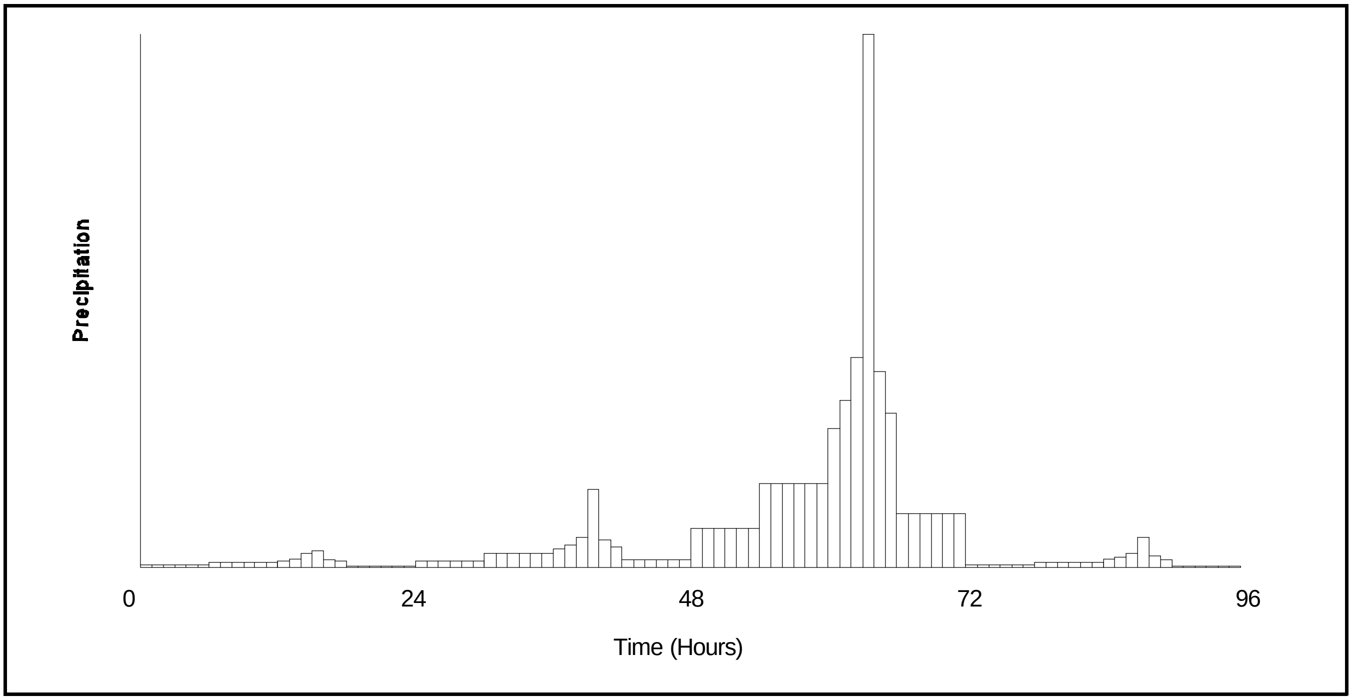

Figure 3-10. Typical SPS precipitation distribution

(2) RUNOFF module. Interior runoff hydrographs may be computed or imported from an external HEC-DSS file. HEC-IFH subbasin runoff parameters include data entry for basin characteristics, unit hydrographs, and loss rates. Data entry for channel routing between the upper and lower subbasins is also included. Figure 3-11 shows a typical subbasin runoff data entry screen. The program is limited to two interior subbasin areas per analysis.

(a) Basin characteristics. The subbasin drainage area and percent imperviousness are entered.

(b) Unit hydrograph. The user may select Clark's, Snyder's, or Soil Conservation Service (SCS) unit hydrographs or enter a unit hydrograph directly. A plot of a typical unit hydrograph used by HEC-IFH is shown in Figure 3-12.

(c) Loss rates. Loss rate methods and parameter values include monthly rates for continuous record analysis and event rates for hypothetical event analyses. Often an adequate representation of the flood volumes is more important than peak flows. Because of this, estimates of the loss rate parameters can be more critical than unit hydrograph and stream routing parameters into HEC-IFH, as illustrated in Figure 3-8. HEC-IFH enables users to select several loss rate options. CSA loss options are generalized runoff coefficients, initial-uniform-recovery method, and no losses. The generalized method is a simple percentage of the rainfall. It is normally used in agricultural areas with daily time intervals and where a significant amount of interior ponding exists. The initial-uniform-recovery is used for most continuous analyses performed by HEC-IFH and includes a simplified method of soil moisture accounting.

HEA loss options are the SCS Curve Number, Holtan, Green-Ampt, Initial-Uniform Methods, and no loss. The method used is largely a user preference based on calibration studies and reasonableness of runoff volumes.

(d) Base flow. Continuous simulation analysis can incorporate monthly rates for base flow. Hypothetical event analysis can incorporate an initial base flow rate and recession variables similar to the HEC-1 program.

(e) Streamflow routing. HEC-IFH has four routing techniques: simple lag method with no flow attenuation, modified Puls, Muskingum, and Muskingum-Cunge methods. The simple lag, the modified Puls, and the Muskingum methods can be used in either CSA or HEA. Muskingum-Cunge is only available in HEA. Modified Puls requires a storage versus outflow relationship and the number of routing steps. Figure 3-13 shows the data entry screen for channel routing. An HEC-IFH plot of a modified Puls storage versus outflow relationship is illustrated in Figure 3-14.

```
HEA 01.04.00
Study ID  RBEND1      Runoff Hydrograph Parameters (RUNOFF)

                          Enter Basin Runoff Data
Basin ID      UPPER1      UPPER BASIN USING SCS UHG & I/U LOSS

Drainage Area (sq mi)                      7.50
Percent of Drainage Area Impervious        15.0

Enter Base Flow Data and Recession      Yes [No]

Infiltration Loss Data               Unit Hydrograph Data
   SCS Curve Number Method              Clark's Unit Hydrograph
   Holtan Method                        Snyder's Unit Hydrograph
   Green-Ampt Method                   [SCS Dimensionless Unit Graph]
  [Initial-Uniform Method ]             Enter Unit Hydrograph
   No Losses Computed



1Help   2PrtScr 3      4      5      6DOS    7      8      9      10Exit
                 Press <F10> to Save Data and Return
```

Figure 3-11. Subbasin runoff data entry

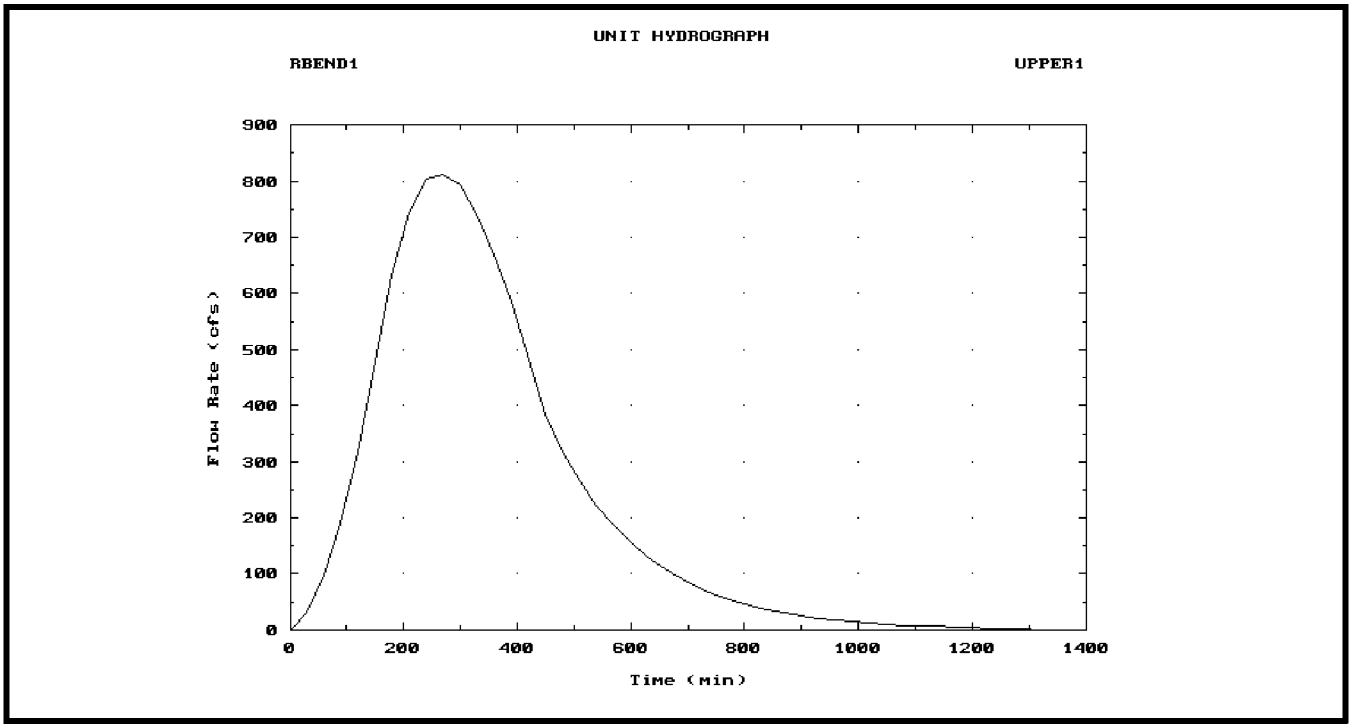

Figure 3-12. Unit hydrograph plot

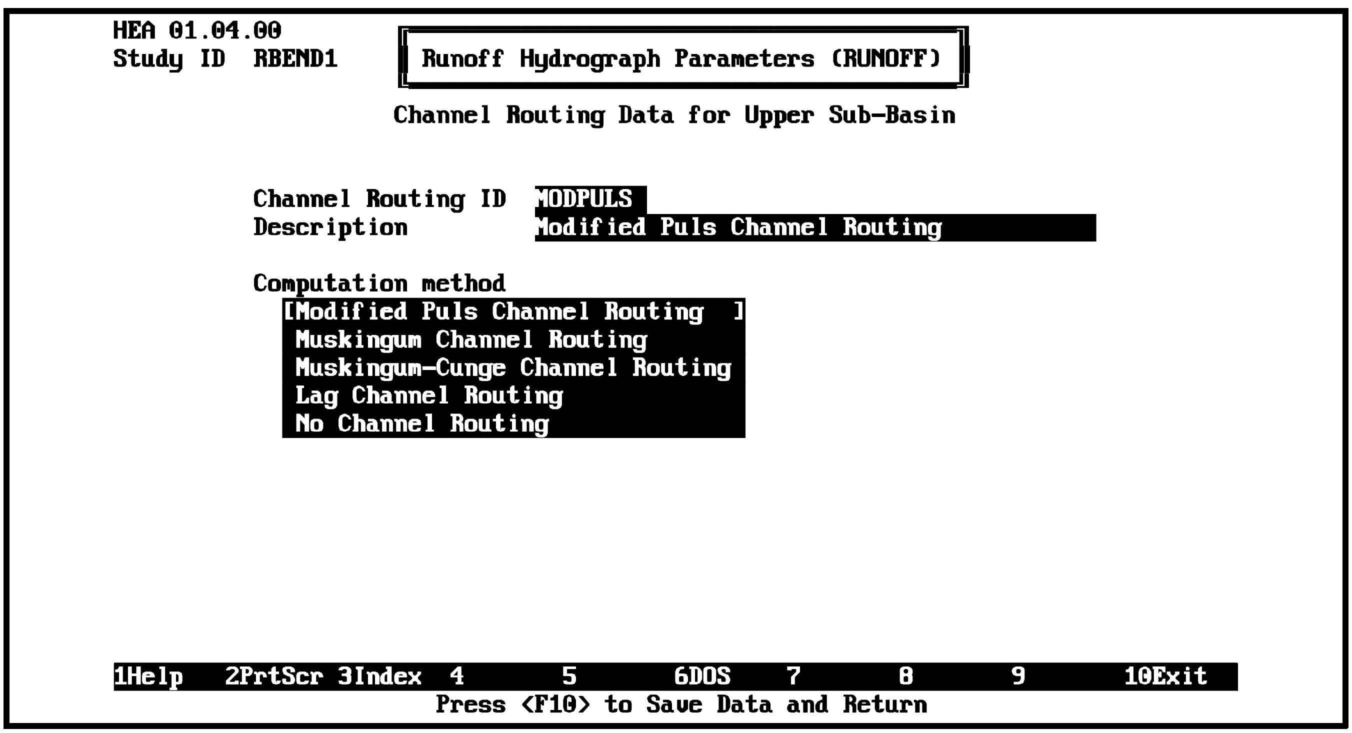

Figure 3-13. Channel routing data entry

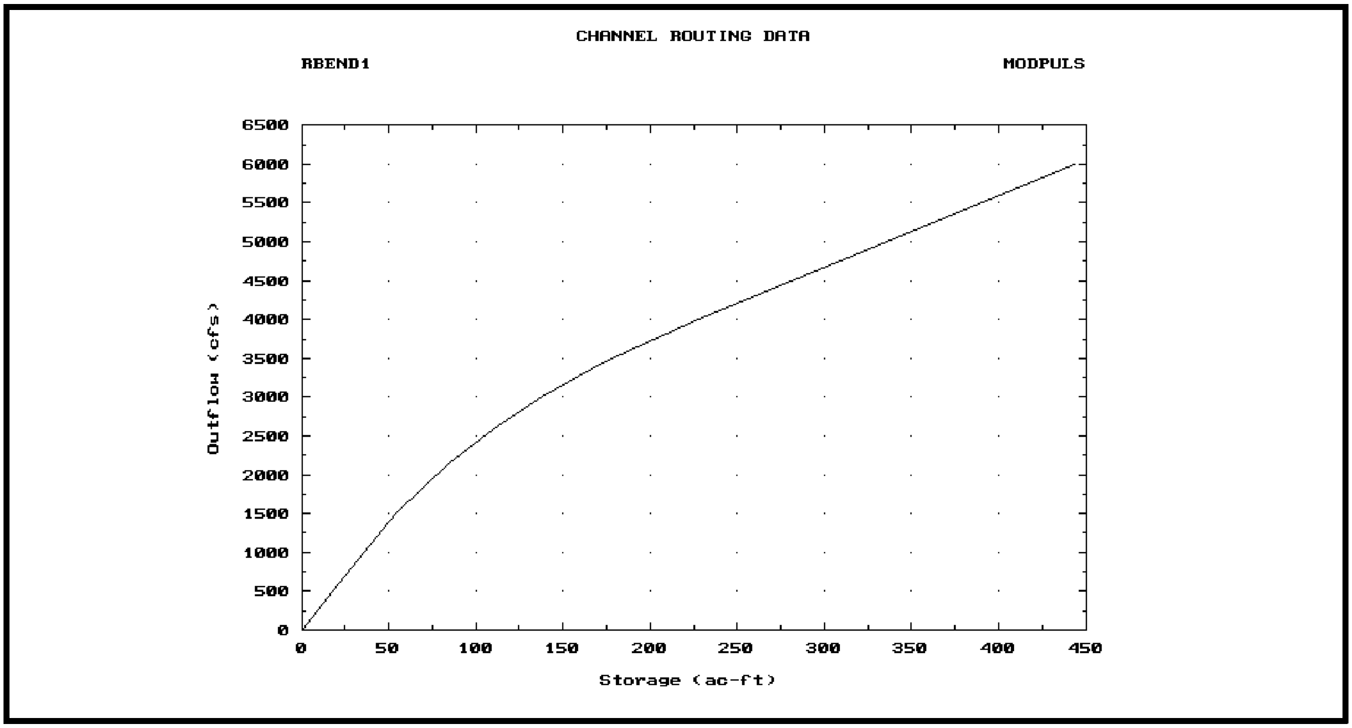

Figure 3-14. Modified Puls storage-outflow plot

For channel routing, the degree of attenuation depends on the number of routing steps used. The number of routing steps is a calibration parameter and represents the number of subreaches into which the total channel reach should be divided. The Muskingum method is defined by three parameters: number of routing steps, Muskingum K coefficient (which is the travel time through the reach), and Muskingum X (which is a weighting factor). The Muskingum-Cunge method is a nonlinear routing technique that is defined by channel length, channel invert slope, channel roughness coefficient, and channel shape. A trapezoid, a circular cross section, or a maximum eight-point cross section are the allowable channel shapes. This method is only available for HEA.

(3) POND module.

(a) Elevation-area relationships for the ponding area adjacent to line-of-protection should be developed using 15-20 points to define the relationship. HEC-IFH automatically generates the storage values. The minimum value should define the pond bottom (zero storage) and must be at the same elevation or below the lowest outlet invert elevation. The maximum value should exceed the highest stage anticipated in the analysis. No extrapolation is performed above or below these maximum or minimum elevations. Figure 3-15 illustrates the ponding area data entry screen and Figure 3-16 shows typical elevation-area-storage for a ponding area.

(b) A ditch rating or discharge-elevation relationship may be entered for a conveyance channel connecting the ponding area to the gravity outlet and/or pump. It is required if the flow is controlled from the ponding area to the primary outlets.

(4) GRAVITY module.

(a) Gravity outlets through the line-of-protection are normally the most cost-effective means of evacuating interior flood waters when the interior stage is greater than the exteriors. Analysis of culvert hydraulics is complex because inlet or outlet controls may govern. The GRAVITY module produces a family of outlet rating curves based on different exterior stage conditions.

(b) HEC-IFH performs gravity outlet analysis by direct entry of the outlet rating or by enabling the user to define the outlet characteristics and a range of computation elevations and intervals for computing the outlet rating curve. Exterior and interior invert elevations define the lower bound of the rating. No flow can occur until the interior ponding elevation exceeds the invert elevation. The interior water elevation must also be greater than the exterior for flow to occur. Figures 3-17 and 3-18 depict the basic data entry screen for the gravity outlet rating computations and the corresponding computed rating table, respectively. Instead of using only the limited data shown in Figure 3-18, the program uses a computed 50x50 matrix of

CSA 01.04.00
Study ID RBEND1

Interior Pond (POND)

Enter Surface Areas for Computing Volumes

Storage Table ID POND1

Description
Interior pond for App. C example.

Pond Elevation (ft)	Surface Area (ac)	Storage Volume (ac-ft)
591.00	0.0	0.0
592.00	4.0	2.0
593.00	10.0	9.0
594.00	15.0	21.5
595.00	75.0	66.5
596.00	130.0	169.0
597.00	200.0	334.0
598.00	275.0	571.5
599.00	400.0	909.0
600.00	525.0	1371.5
601.00	700.0	1984.0
605.00	2000.0	7384.0
0.00	0.0	0.0

1Help 2PrtScr 3 4 5 6DOS 7 8 9 10Exit

Press <F10> to Save Data and Return

Figure 3-15. Ponding surface area data entry screen

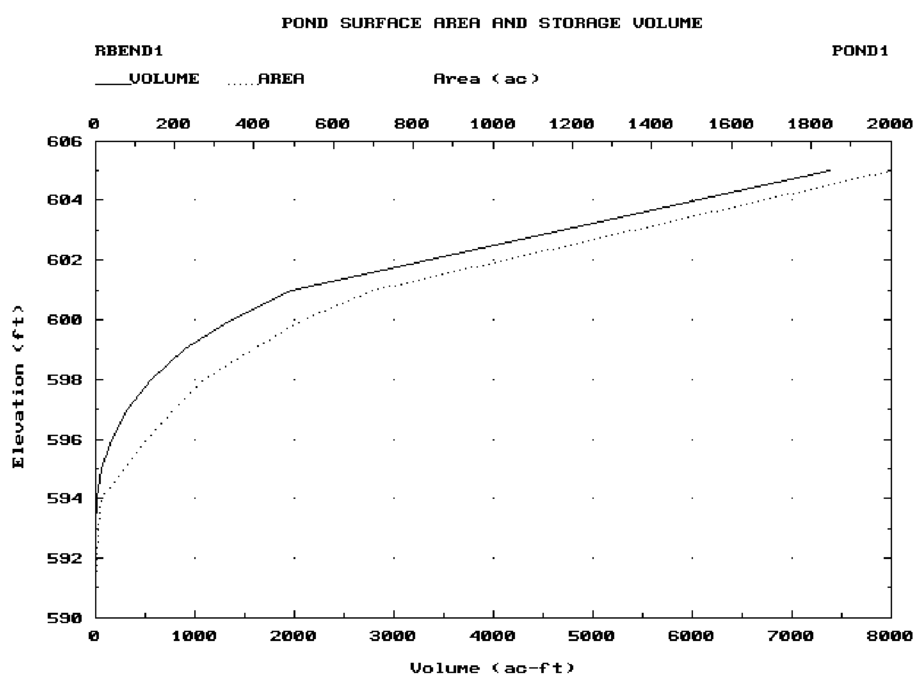

Figure 3-16. Pond surface area and storage volume plot

```
CSA 01.04.00
Study ID  RBEND1                Gravity Outlets (GRAVITY)

               Compute Gravity Outlet Rating Table for Culvert

             Outlet Structure ID  4X4BOX
             Description          Single 4x4 Box culvert.

             Culvert Type:                             [Box] Circular

             Number of Identical Outlets                     1
             Length (ft)                                200.00
             Manning's n                              0.012000
             Entrance Loss Coefficient                0.400000

           * Tailwater Tabulation Interval (ft)           4.00
          ** Flow Capacity Tabulation Interval (cfs)      20.0

             Exterior Outlet Invert Elevation (ft)      589.00
             Interior Outlet Invert Elevation (ft)      591.00
             Exterior Elevation for Gate Closure (ft)   605.00

* 1/7th the expected elevation range        ** 1/20th the expected flow range
1Help   2PrtScr 3      4      5      6DOS    7      8      9      10Exit
                      Press <F10> to Save Data and Return
```

Figure 3-17. Data entry screen for culvert computations

```
CSA 01.04.00
Study ID  RBEND1                Gravity Outlets (GRAVITY)
Struc.ID  4X4BOX
                  View Computed Gravity Outlet Rating Table
```

Flow Capacity (cfs)	Headwater Elevation (ft)						
	No TailWater	TailWater Elev. 1 593.00	TailWater Elev. 2 597.00	TailWater Elev. 3 601.00	TailWater Elev. 4 605.00	TailWater Elev. 5 609.00	TailWater Elev. 6 613.00
0.0	591.00	593.00	597.00	601.00	605.00	609.00	613.00
20.0	* 592.42	593.05	597.05	601.05	605.05	609.05	613.05
40.0	* 593.30	* 593.30	597.22	601.22	605.22	609.22	613.22
60.0	* 594.04	* 594.04	597.49	601.49	605.49	609.49	613.49
80.0	* 594.71	* 594.71	597.87	601.87	605.87	609.87	613.87
100.0	* 595.34	* 595.34	598.36	602.36	606.36	610.36	614.36
120.0	* 596.29	* 596.29	598.96	602.96	606.96	610.96	614.96
140.0	* 597.17	* 597.17	599.66	603.66	607.66	611.66	615.66
160.0	* 598.07	* 598.07	600.48	604.48	608.48	612.48	616.48
180.0	* 599.09	* 599.09	601.40	605.40	609.40	613.40	617.40
200.0	* 600.24	* 600.24	602.44	606.44	610.44	614.44	618.44

```
1Help   2PrtScr 3      4      5      6DOS    7      8      9Plot  10Exit
* Inlet Control              Press <PgDn>, <PgUp> or <F10>
```

Figure 3-18. Computed gravity outlet rating table headwater versus tailwater with discharge as the matrix's internal elements to interpolate outlet discharge.

(c) Gravity outlets are open whenever the interior water elevation exceeds the exterior elevation by a user-specified minimum value (head). The outlet is assumed closed for all other conditions. A different operation is performed if a gate closure value is specified. Gravity flows are then assumed to cease when the exterior stage exceeds the gate closure elevation. Up to five gravity outlets may be entered at the primary location and for each of the four secondary locations. Chapter 6 of the HEC-IFH user's manual provides detailed descriptions of the gravity outlet data entry and analysis options.

(5) PUMP module.

(a) The PUMP module specifies pump characteristics used to determine the amount of water pumped from the interior area during flood events. Up to ten different pumping units may be defined for an interior area. The station is assumed to be located at the primary outlet.

(b) The pumping facilities are defined by a total head-capacity-efficiency relationship, shown in Figure 3-19. It is normally determined from mechanical and/or electrical engineering analyses. For standard type pumps, the information may be obtained from the pump manufacturers. The head loss represents the lump sum of all various losses due to friction, bends, contractions, expansions, entrance, and exit for the pumping unit. The total head represents the operating head at various pumping outflow capacities. It is computed as the sum of the head loss and static head (exterior elevation minus interior elevation). The final value of head is entered in the total head column. It is the maximum head against which the pump can discharge water from the interior. If the maximum head is exceeded, the pump is assumed to shut off.

(c) The user may also specify pump start and stop elevations on a monthly basis as shown in Figure 3-19. This flexibility is useful where seasonal operation requires different pumping and interior ponding operation criteria such as for agricultural or environmentally sensitive areas. On-off elevations are typically constant throughout the year in urban areas. Chapter 7 of the HEC-IFH user's manual provides a detailed description of the PUMP module.

(6) EXSTAGE module.

(a) The exterior stage module defines the stage hydrograph in the channel exterior to the line-of-protection. Exterior stage represents tailwater elevations that effect seepage and outflow of the gravity outlet and pumping stations of the interior area. For CSA, a continuous exterior stage hydrograph is required. For HEA, exterior stage hydrographs are required for each event analyzed. The magnitude of the exterior stages and their coincidence with interior runoff/inflow affect outflow and,

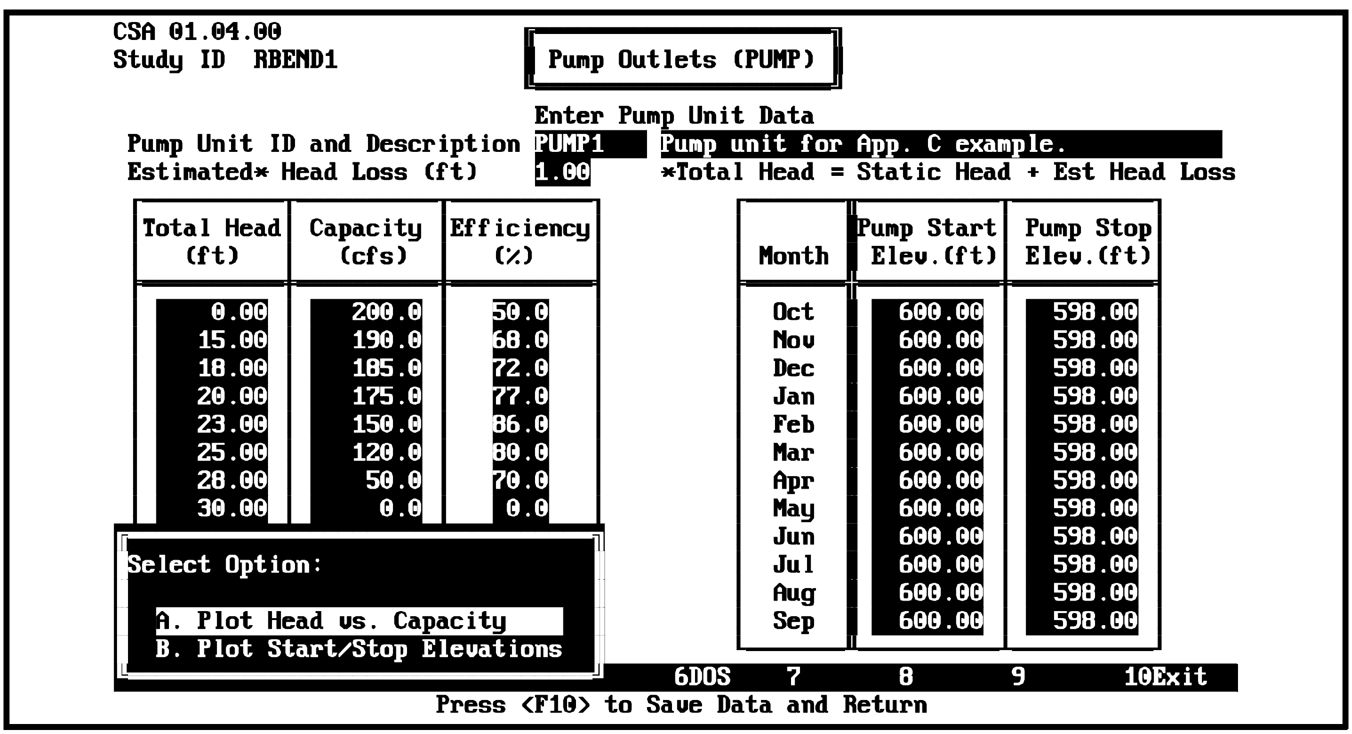

Figure 3-19. Pump unit data entry screen for continuous simulation analyses

therefore, interior ponding elevation.

(b) Exterior stage hydrographs may be entered directly, computed from discharge hydrographs and rating curves, or computed from rainfall-runoff as defined in a PRECIP and RUNOFF module (exterior subbasin) and rating curve. The latter is used where there is a high degree of dependence and coincidence between exterior and interior events.

(c) HEC-IFH can transfer exterior stages (such as from a nearby gauge) to another upstream or downstream location using river transfer relationships. Figure 3-20 illustrates the concept of relating data from the index location to another location based on the slope in the water surface profiles. Evaluation of interior systems with outlets on a tributary to the main stem where the exterior stages at the outlet are affected by the main stem backwater may also be performed. Chapter 8 of the HEC-IFH user's manual describes the EXSTAGE module and data entry options in detail.

(7) AUXFLOW module. The AUXFLOW module defines external flow into the system, overflow and diversion out of the system, and seepage inflow from the exterior river to the interior area. Chapter 9 of the HEC-IFH user's manual describes in detail the AUXFLOW module.

(a) Head-versus-seepage relationships. A secondary inflow into the ponding area is seepage through or under the line-of-protection during high exterior river stages. A relationship of seepage rate versus differential head between the interior pond and the exterior river stage is generally estimated by the geotechnical member of the study team. It is based on soil materials of the levee and pumping tests of interior relief wells for an existing levee project, or estimated from a similar project (preferably in the same river basin). On a potentially large study, money may be available for subsurface investigation early enough to coordinate with the geotechnical engineer to have a pump test at one or more boring locations. Generally seepage is lagged 1 day to simulate the flow rate along the seepage path.

(b) Auxiliary inflow. Auxiliary inflows provide means to enter hydrographs from adjacent areas or to compute them using methods other than in HEC-IFH. For example, a more detailed analysis of a complex system (more than two subbasins) may be performed using HEC-1 or another program and the hydrographs imported into HEC-IFH from HEC-DSS. HEC-1 may be used to compute hypothetical runoff hydrographs using the kinematic wave in an urban area. Similarly, a continuous runoff record generated from a more detailed moisture accounting program could be imported and used in HEC-IFH. Data for the PRECIP and RUNOFF modules would not be required in these cases. Another application of auxiliary inflow is to import overflow from an adjacent interior area into HEC-IFH for the area under study. This would be applicable where adjacent subbasins have a cascading effect and are analyzed as separate interior areas. Appendix D provides a case example application that uses auxiliary inflows.

(c) Diversions. Diversions transfer all or portions of the runoff from one location to another. Diversions may be made to remove flow from an upper subbasin to the exterior river via a pressure conduit. They may be designed to alter all flows or to convey flows above or below some target value.

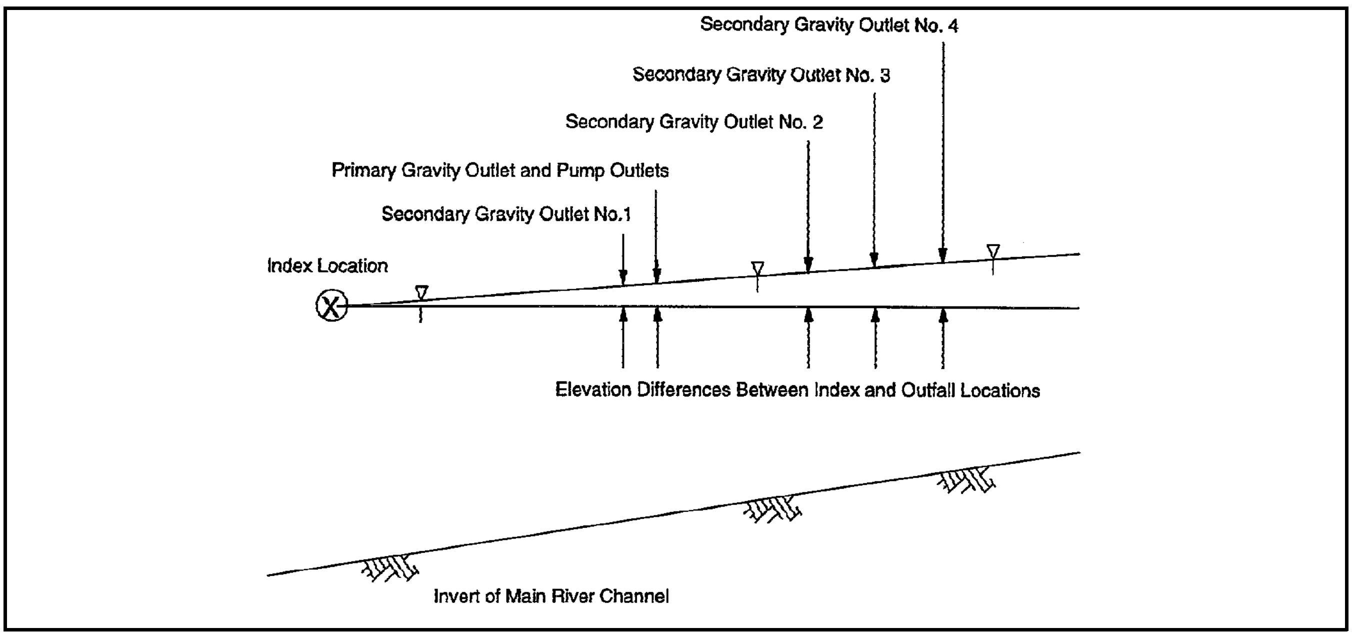

Figure 3-20. Main river transfer concept: slope-profile

(d) Overflow. Overflows occur when an interior ponding area exceeds the available storage, which causes flows to spill into an adjacent interior area. HEC-IFH assumes that the flow leaving the original interior area does not return to that area. The overflow is defined by specifying a pond elevation-overflow discharge relationship.

3-7. Interior Analysis

a. Plan development. The interior analysis may be performed after the input data entry is completed. The analysis defines a plan that consists of a unique combination of modular data for precipitation, runoff, exterior stage, and interior facilities. Figure 3-21 shows the data screen used to specify the various data modules that comprise the plan.

A study typically will have different plans. The first plan may describe a minimum gravity outlet, a second plan may include additional gravity outlet capacity, and a third plan may include a pumping station. Each plan is given a unique plan ID. The plan ID is used to identify the plan results.

b. Analysis time.

(1) The “Beginning Date for Analysis” and “Ending Date for Analysis” are entered as shown in Figure 3-21. The standard HEC-DSS format for time series data is used. The beginning date is the end of the first computation interval, and the ending date is the end of the last computation interval in the analysis. For example, hourly values for the month of October 1990 would have a beginning date of 01OCT1990/0100 and an ending date of 31OCT1990/2400. If the analysis of October 1990 consisted of daily instead of hourly values, the starting date would be 01OCT1990/2400 (the end of the first day), and the ending date is not changed.

(2) The specified beginning and ending date should be consistent with the starting and ending periods of time series used as input for the calculations. After the dates are specified, HEC-IFH checks all precipitation, exterior stage, and auxiliary inflow time series used in the plan. If any of these time series start after the beginning date of the interior analysis, or end before the ending date of the analysis, the interior analysis will proceed using zero (0) for all missing values. If so, a message is written to the error warning message file.

c. Computation time interval.

(1) General. The computation time interval, shown in Figure 3-21, is the time-step for all subbasin runoff, channel routing, and pond routing computations for the interior analysis. This value must be between 5 min and 24 hr. Choosing an appropriate time interval is important. If the primary interior problem is providing facilities to handle the volume of water reaching the line-of-protection (such as a large ponding area in an agricultural area), a long computational time interval of up to

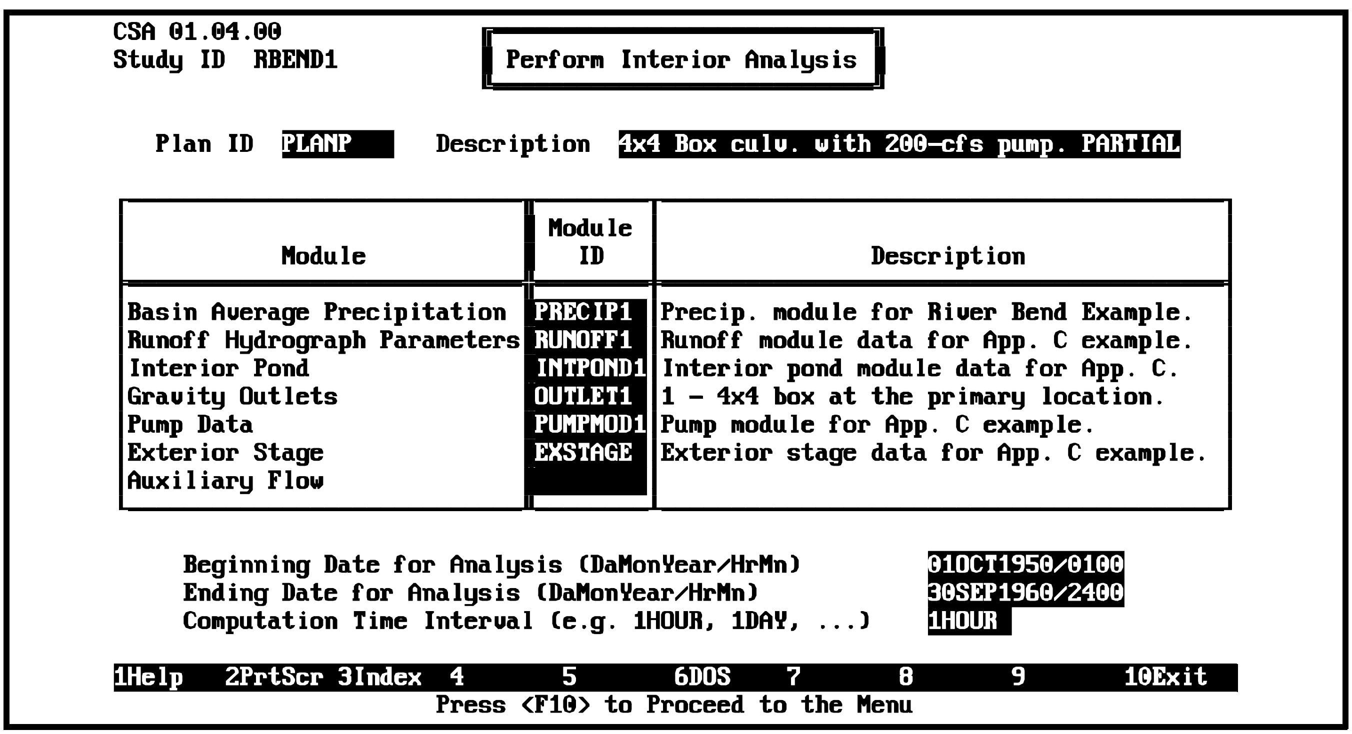

Figure 3-21. Plan specification screen

1 day may be appropriate. If the problem is providing facilities to handle peak flow reaching the line-of-protection (such as for an urban area with little or no ponding volume), then a short time interval is required. A good test is to analyze a plan configuration using several time intervals until the results are consistent, especially the stage-frequency relationship.

(2) Effect of the Computational Time Interval on Other Computations. Selection of a computation time interval can affect the validity and numerical stability of several computations. Shorter time intervals generally provide more stable results. If the output results indicate a significant difference between total inflow and outflow volume, a shorter time interval may be required.

d. Interior analysis computation sequence. After the plan is specified, the screen illustrated in Figure 3-22 is displayed. This menu controls the interior analysis computations performed for a single operation. Five options are available:

- **Perform Upper Sub-Basin Analysis (Option A).** Compute the runoff hydrograph for the upper interior subbasin using the precipitation record from the PRECIP module and the infiltration loss, unit hydrograph, and base flow parameters from the RUNOFF module. Add the auxiliary inflow for the upper subbasin. Subtract the diversion from the upper subbasin. Route the resulting hydrograph downstream to the lower subbasin.

- **Perform Lower Sub-basin Analysis (+ Upper as needed) (Option B).** Execute Option A, if appropriate and if not already executed. Then, compute a runoff hydrograph for the lower interior subbasin using the precipitation record, infiltration loss, base flow, and unit hydrograph parameters. Add the auxiliary inflow for the lower subbasin. Combine the routed hydrograph from the upper subbasin, if present as a result of Option A above.

- **Perform Exterior Basin Analysis (Option C).** Execute Options A and B, if appropriate and if not already executed. Then, compute the exterior stage hydrograph at the primary outlet location using the data specified in the exterior stage module.

- **Perform Pond Routing Analysis (+ Upper, Lower, Exterior as needed) (Option D).** Execute Options A, B, and C, if appropriate and if not already executed. Then, compute the pond stages and outflows for each time period throughout the analysis using the data for the interior pond, gravity outlets, pumps, seepage, overflow, exterior stage, and combined inflow hydrograph.

- **Perform Frequency Analysis (+ Upper, Lower, Exterior, Pond as needed) (Option E).** Execute Options A, B, C and D, if appropriate and if not already executed. Then, compute a graphical annual or partial duration series interior

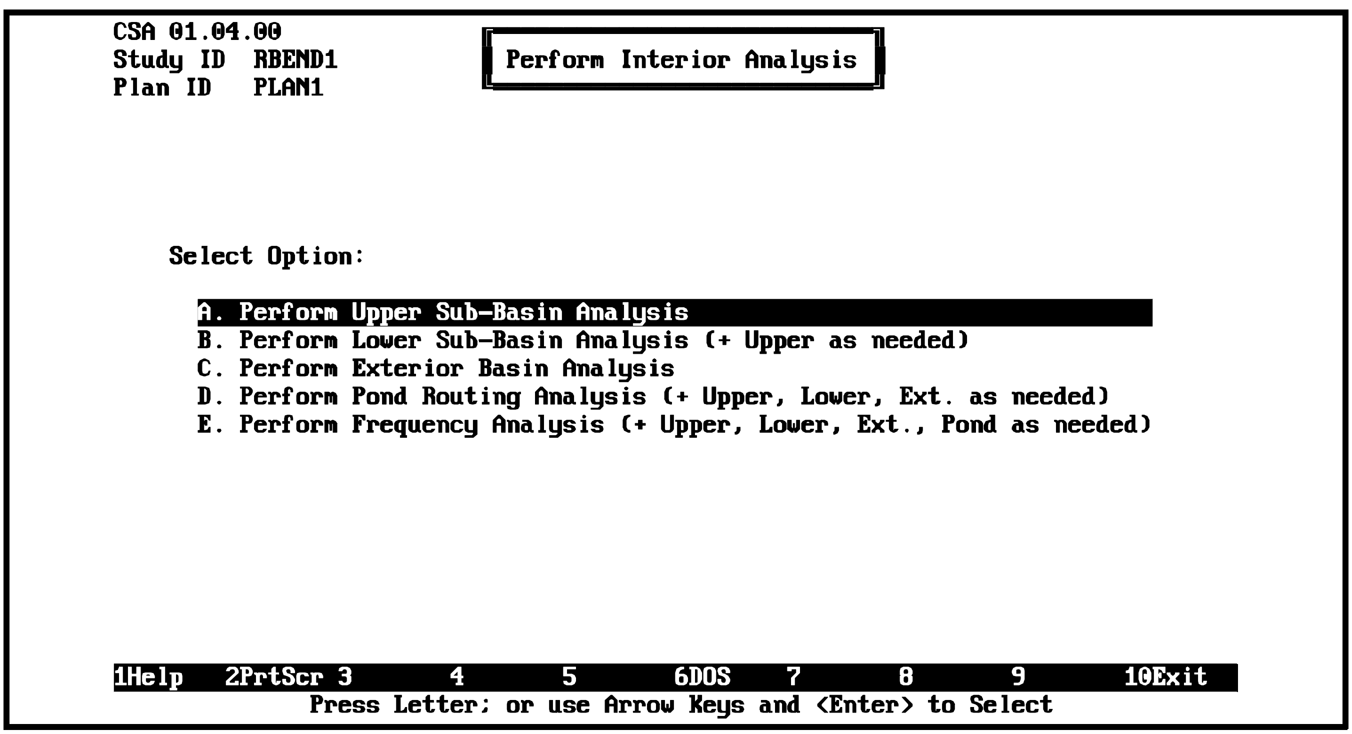

Figure 3-22. Interior analysis menu

area elevation-frequency and duration relationship using the computed interior stage hydrograph.

e. Interior pond routing parameters.

(1) The "Starting Pond Elevation" of Figure 3-23 is the interior storage pond elevation at the beginning of the analysis. The starting pond elevation must be within the range of elevations specified in the pond elevation-surface area table. If the starting pond elevation is below the minimum elevation, or above the maximum elevation, HEC-IFH adjusts the starting elevation to the minimum or maximum value as appropriate. It also writes a warning message to the plan message file.

(2) The "Minimum Head of Gravity Outlet Operation" specifies the minimum positive differential head (interior minus exterior water surface elevation) necessary before the gravity outlets will operate. Some levee systems close the gravity outlets when the exterior water surface elevation rises to a level close to the interior water surface elevation. The user may specify gates on gravity outlets that require a small head differential before the outlet will open. Any value greater than or equal to zero may be entered.

(3) The "Operate Pumps, Gravity Outlets Simultaneously?" option requires a "yes or no" response. If "Yes" is selected, then the pumps and gravity outlets operate independently. They may operate simultaneously at times during the analysis. If "No" is selected, then pumps and gravity outlets do not operate simultaneously. In this case, the pumps are assumed to stop when the gravity outlets are discharging.

3-8. Analytical Procedures

An overview of procedures used to perform the CSA and HEA analyses are described in the following subsections.

a. Analytical procedures for CSA. HEC-IFH continuous simulation analyses are performed in the following sequence:

(1) Rainfall. Enter continuous record rainfall data for a single gauge or several gauges. If appropriate, compute the composite basin average precipitation for a subbasin as the weighted average of measurements for up to five individual rain gauges. Chapter 3 of the HEC-IFH user's manual describes rainfall data entry.

(2) Rainfall excess. Compute subbasin rainfall excess values using either the generalized runoff coefficients or the initial-uniform recovery method. Chapter 4 of the HEC-IFH user's manual describes these methods.

(3) Runoff. Transform rainfall excess into a runoff hydrograph for each interior subbasin using user-defined unit hydrograph methods. Add base flows to the computed runoff hydrographs. Chapter 4 of the HEC-IFH user's manual describes these methods.

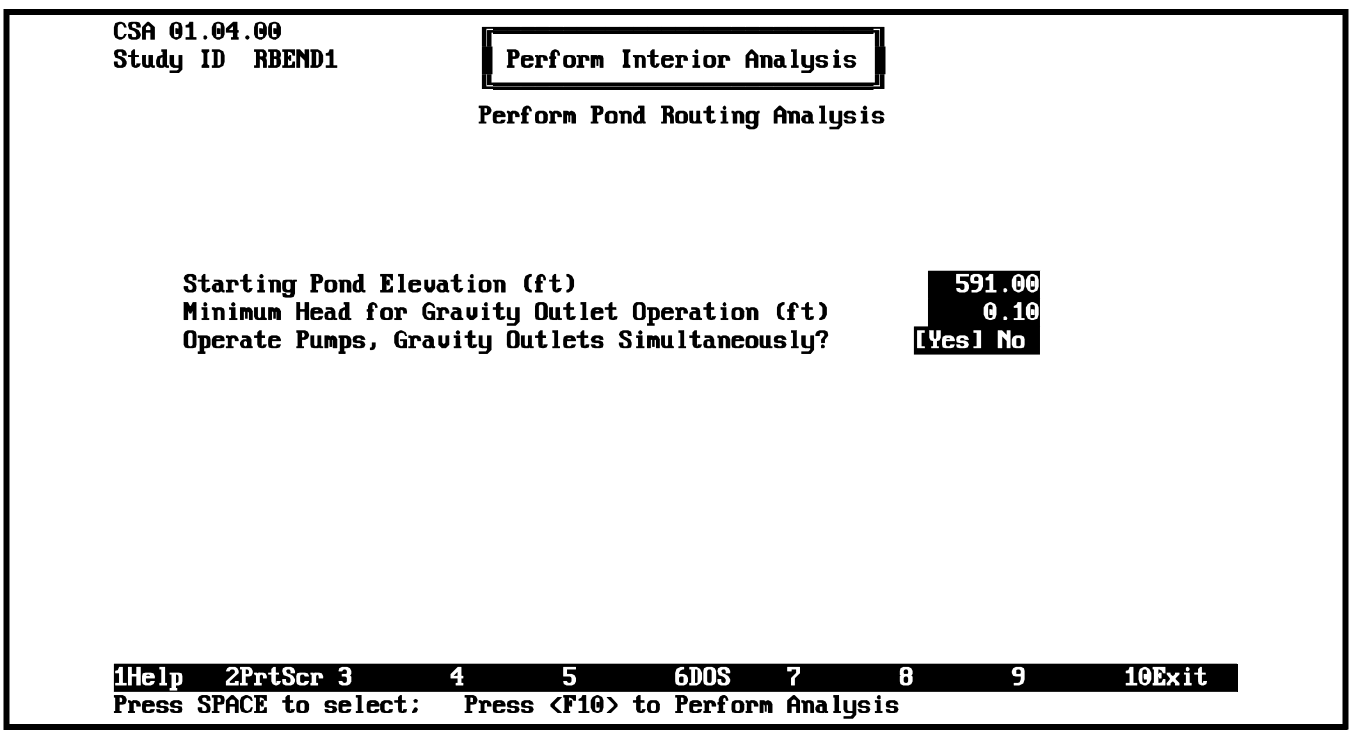

Figure 3-23. Pond starting conditions screen

(4) Auxiliary flows. Determine auxiliary flows such as diversions from the upper interior drainage area, overflow from an adjacent lower area, or seepage through the levee. Chapter 9 of the HEC-IFH user's manual discusses auxiliary flows.

(5) Channel routing. Route the total discharge hydrograph from the upper portion of the interior area to the interior ponding area using the modified Puls, Muskingum, or Lag methods. Chapter 4 of the HEC-IFH user's manual discusses channel routing.

(6) Exterior stages. Define exterior stage data using an exterior stage hydrograph or an exterior discharge hydrograph and channel rating curve. Exterior discharge hydrographs may also be computed using the same rainfall-runoff methods described for interior discharge hydrographs. Chapter 8 of the HEC-IFH user's manual describes exterior stage data.

(7) Pond routing. Route interior inflow through the ponding area and discharge it through the line-of-protection via the gravity outlets and/or pumping stations. Seepage and auxiliary flows into or out of the ponding area are included in the pond analysis. Chapter 5 of the HEC-IFH user's manual describes the interior pond module, while Chapter 10 describes the interior pond routing computations. The gravity outlet rating curve, the pump outlet capacity, and seepage and overflows are described in Chapters 6, 7, and 9, respectively, in the user's manual.

(8) Results analysis. Develop elevation-frequency relationships, duration of flooding, and other pertinent hydrologic information from the analysis results. Chapter 11 of the HEC-IFH user's manual documents the program results, output tables, and plots.

b. Analytical procedures for HEA. HEC-IFH program procedures for hypothetical event analysis are performed in the following sequence:

(1) Rainfall. Enter hypothetical storm depth-duration-frequency data for individual or multiple hypothetical events historic storms and/or for the SPS. Hypothetical frequency storms are balanced storm distributions with total rainfall amounts consistent with specific exceedance frequencies or recurrence intervals. The program can consider the 0.2-percent (500-year), 1-percent (100-year), 2-percent (50-year), 4-percent (25-year), 10-percent (10-year), 20-percent (5-year), and 50-percent (2-year) frequency storms. The SPS is determined according to the criteria discussed in EM 1110-2-1411. Chapter 3 of the HEC-IFH user's manual describes rainfall data entry.

(2) Rainfall excess. Compute rainfall excess for each interior subbasin using SCS curve number, Holtan, Green-Ampt, or the Initial-Uniform methods. Chapter 4 of the HEC-IFH user's manual describes these methods.

(3) Runoff. Transform rainfall excess into a runoff hydrograph for each interior subbasin. Unit hydrographs may be entered directly, or computed using the Clark, Snyder, or SCS Dimensionless unit hydrograph methods. Compute base flow and base flow recession. Chapter 4 of the HEC-IFH user's manual discusses the available unit hydrograph methods.

(4) Auxiliary flows. Determine auxiliary flows such as diversions from the upper interior area, overflow from an adjacent lower area, and levee seepage. Chapter 9 of the HEC-IFH user's manual describes auxiliary inflows and diversions.

(5) Channel routing. Route the total discharge hydrograph from the upper portion of the interior area to the interior ponding area. The modified Puls, Muskingum, Muskingum-Cunge, or Lag methods are available. Streamflow routing is discussed in Chapter 4 of the HEC-IFH user's manual.

(6) Exterior stages. Define exterior stage data using an exterior stage hydrograph or an exterior discharge hydrograph and channel routing curve. Exterior discharge hydrographs may be computed using the same methods described for interior discharge hydrographs. Chapter 8 in the HEC-IFH user's manual describes exterior stage data.

(7) Pond routing. Route interior inflow through the ponding area and discharge it through the line-of-protection via the gravity outlets and/or pumping stations. Include seepage flows through the line-of-protection, as well as overflows from the ponding area. Gravity outlet rating curves, pump station capacity, seepage/diversions, and interior pond routing computations are described in Chapters 6, 7, 9, and 10, respectively, in the HEC-IFH user's manual.

(8) Analysis results. Determine the interior elevation-frequency relationships and other results from the computation outputs of the HEC-IFH program.

3-9. Analysis Summaries

HEC-IFH has extensive reporting capabilities. Table 3-1 provides an overview of the output capabilities for both the CSA and HEA options. Figures 3-24 and 3-25 show the hydrologic analysis summary screens, from which the user may view the output and print results. Chapter 12 of the HEC-IFH user's manual provides a detailed description of the output summary capabilities of HEC-IFH.

3-10. Plan Comparison

The HEC-IFH program enables users to compare the performance of various plans in tables and graphically. Figures 3-26 and 3-27 show users options for plan comparison for the CSA and HEA. Chapter 13 of the HEC-IFH user's manual provides details on the plan comparison capabilities.

Table 3-1
Overview of HEC-IFH Hydrologic Analysis Summaries

Type of Output	Continuous Simulation Analysis	Hypothetical Event Analysis
Input data	Analysis input summaries	Analysis input summaries
Detailed output	Calculation period summaries	Analysis by events
Monthly totals/averages	Monthly summaries	-
Annual totals/averages	Water year annual summaries	-
Summary of all results	Analysis record summaries	Event comparisons
Error messages	Analysis, warning/error messages	Analysis, warning/error messages

```
CSA 01.04.00
Study ID  RBEND1      Hydrologic Analysis Summaries       Begin 01OCT1950/0100
Plan ID   PLANP                                           End   30SEP1960/2400

Analysis Input Summaries                   Water Year Annual Summaries
   A. Data Management Summary                 N. Rainfall-Runoff Data
   B. Rainfall-Runoff Summary                 O. Interior/Exterior/Pump Data
   C. Gravity Outlet Data                     P. Maximum Area Flooded
   D. Pump Station Data

Calculation Period Summaries               Analysis Record Summaries
   E. Rainfall-Runoff Data                    Q. Maximum Values
   F. Interior/Exterior Data                  R. Inflows and Outflows
   G. Detailed Inflow Data                    S. Exceedance Duration Table
   H. Detailed Outflow Data                   T. Plotting Position Table
   I. Detailed Grav. Outflow Data             U. Stage-Frequency Table
   J. Area Flooded Data                       V. Pump Operation

Monthly Summaries                          Analysis Error Messages
   K. Average Monthly Rainfall                W. List Warning/Error Messages
   L. Interior/Exterior Data
   M. Pump Operation

1Help   2PrtScr 3       4       5       6DOS    7       8       9       10Exit
              Press Letter; or use Arrow Keys and <Enter> to Select
```

Figure 3-24. Menu of continuous simulation hydrologic analysis summaries

3-11. Summary

Feasibility studies are conducted within the framework of ER 1105-2-100, with specific hydrologic engineering guidance found in EM 1110-2-1413. If HEC-IFH is to be applied, the hydrologic engineer should review and understand the concepts and application capabilities of the program as described in the HEC-IFH user's manual (USACE 1992). Once the program is installed and running, and the test problems yield correct results, the study is ready to be conducted.

```
HEA 01.04.00
Study ID  RBEND1          Hydrologic Analysis Summaries
Plan ID   PLANP

 Analysis Input Summaries                 Event Comparisons
    A. Data Management Summary               M. Rainfall-Runoff Data
    B. Rainfall-Runoff Summary               N. Maximum Flows
    C. Gravity Outlet Data                   O. Flood Volumes
    D. Pump Station Data                     P. Gravity Outlet Analysis
                                             Q. Pump Analysis
                                             R. Frequency Analysis
 Analysis by Events
    E. Rainfall-Runoff Data               Analysis Error Messages
    F. Interior/Exterior Data                S. List Warning/Error Messages
    G. Detailed Inflow Data
    H. Detailed Outflow Data
    I. Detailed Grav. Outflow Data
    J. Area Flooded Data
    K. Maximum Values
    L. Inflows and Outflows

1Help   2PrtScr 3       4       5       6DOS    7       8       9       10Exit
              Press Letter; or use Arrow Keys and <Enter> to Select
```

Figure 3-25. Menu of hypothetical event hydrologic analysis summaries

```
CSA 01.04.00
Study ID  RBEND1               Comparison of Plans


                    Analysis Summaries
                      A. Maximum Values
                      B. Flood Volume Data

                    Gravity Outlet Analysis
                      C. Outflow Volumes
                      D. Days Blocked

                    Pump Analysis
                      E. Capacity Summary and Days Pumped

                    Interior Analysis
                      F. Maximum Interior Elevations
                      G. Duration of Interior Flooding
                      H. Maximum Interior Area Flooded

1Help   2PrtScr 3       4       5       6DOS    7       8       9       10Exit
              Press Letter; or use Arrow Keys and <Enter> to Select
```

Figure 3-26. Continuous simulation plan comparison summary menu

```
HEA 01.04.00
Study ID  RBEND1                    Comparison of Plans



                  Select Option:

                    A. Plan Summary
                    B. Maximum Interior Elevation-Frequency
                    C. Maximum Interior Area Flooded-Frequency
                    D. Maximum Total Interior Inflow-Frequency




1Help   2PrtScr 3      4      5      6DOS   7      8      9      10Exit
              Press Letter; or use Arrow Keys and <Enter> to Select
```

Figure 3-27. Hypothetical event plan comparison summary menu